

APPLICATION OF LOW-COST TURBO-JET POWERED INTERCEPTORS FOR CRUISE MISSILE DEFENSE

Gary T. Jimmerson, U.S. Army AMCOM RDEC & Hans J. Dall, Northrop Grumman, Associate Fellow

ABSTRACT

With the proliferation of highly accurate long-range cruise missiles and the demonstrated capabilities of this type of weapon, defense against this threat is becoming an essential military requirement. Furthermore, the inherent characteristics of evolving cruise missiles, such as low cost, long range, payload mix and numerous launch options, are making cruise missiles a weapon of choice for many military planners. As a result, potential adversaries could soon possess sufficiently large numbers of this type of weapon that cannot be cost effectively addressed with available U.S. air defense systems. What is needed is a low-cost ground launched interceptor that can fulfill this critical need.

This paper will detail the concept for such an affordable cruise missile defense system. It will include the Concept of Operations (CONOPS), a definition of the integrated system and detail the innovative use of current sensors and other technologies. Analytical and simulation results are utilized as the basis for the development of the concept and evaluation of its expected capabilities.

THE EMERGING THREAT

The variety of airborne threats facing military planners has complicated the strategic air defense strategies. A trend in the use of these threats is toward the proliferation of low cost unmanned platforms. These platforms may be performing a multitude of roles including Reconnaissance, Intelligence, Surveillance, and Target Acquisition (RISTA) or transporting payloads of mass destruction in swarms of saturating numbers. The availability of these low cost, relatively unsophisticated platforms have flourished in recent years, thereby making it available, viable and affordable for almost anyone to acquire them.

To offset the impact of the low cost platforms and the more sophisticated threats, a multi-tiered defense approach has evolved to counter each of the specific threats. This multi-tiered defense approach has both vertical and horizontal defense in-depth components. This paper provides an approach to address the horizontal defense in-depth issue. The horizontal defense in-depth can be described as a tactic to engage the threat as quickly as it is detectable, as deep as possible (preferably while over hostile territory) and, if necessary, engage the threat multiple times until it is eliminated.

THE RESULTING NEED

The Program Executive Office, Air and Missile Defense (PEO AMD), has identified several needs that a Low Cost Interceptor (LCI) could meet. The major thrust of the PEO's need in an LCI-class interceptor is to achieve cost efficiency in defeating the enemy air and missile threats. Today's systems are desired to provide a cost-effective solution to the defense need. Yet, it must be designed to defeat the most stressing characteristics of the postulated threat set in the worst of the natural and man-induced environmental conditions. This design paradigm results in interceptors that are robust, highly capable, and relatively expensive. However, as illustrated in Figure 1, the expected future threat is evolving into one that employs a significant number of cheap, saturating weapons and reserves their stressing, expensive weapons to achieve very high-value tactical and strategic objectives. The result of the current design paradigm is that the cheap, saturating threat is countered with the same sophisticated interceptor that is used to kill the stressing, expensive threats. This results in a very asymmetrical cost per kill in favor of the enemy. By designing a missile to supplement the expensive, sophisticated interceptors, we achieve closer symmetry between enemy cost to attack and our cost to defend. To achieve this cost ratio balance of attack to defend, the LCI vehicle design goal is to have a flyaway unit cost of less than \$100K.

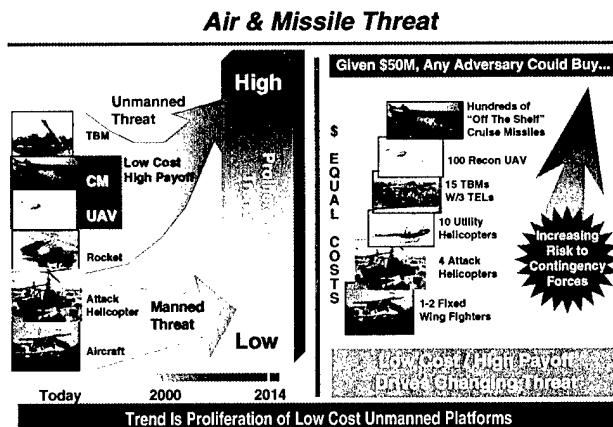


Figure 1: Evolution to Low-Cost, High Payoff Threats

There are additional opportunities in the Army's air and missile defense modernization strategy where LCI could supplement our sophisticated, highly capable fleet of interceptors. The resultant capability is a system of

systems combining high performance and cost efficient interceptors that will effectively and efficiently counters the full threat spectrum.

Early in this decade, an extended range capability in the Short-Range Air Defense (SHORAD) force must be fielded. The current Stinger missile is limited to line-of-sight engagements within a range-limited kinematic intercept capability and cannot defeat the standoff threats such as helicopters firing anti-tank guided missiles or unmanned aerial vehicles conducting RISTA. A ground-launched variant of the Advanced Medium Range Air-to-Air Missile (AMRAAM) is an option for this mission. However, the limitations of the AMRAAM in this role can be expected to result in product improvement efforts to upgrade the seeker to improve clutter rejection and an upgrade to increase the range by a factor of three. As a result, the product improved AMRAAM will likely provide far less engagement range than LCI at several times the required cost per kill. The first window of opportunity for LCI insertion into a modernization effort will occur about 2005 to 2007 in the form of a Milestone Decision Review (MDR) to produce and field a system that can provide greater in-depth horizontal defense.

Longer-term applications for LCI that are envisioned are the Medium Extended Air Defense System (MEADS) and the Enhanced Area Air Defense (EAAD) capability. The United States Army Air Defense Artillery School (USAADASCH) has developed a strategy for controlling MEADS costs by planning to fill half the launchers in a MEADS battle element with PATRIOT Advanced Capabilities – 3 (PAC-3) missiles and half with extended range ground-launched AMRAAM missiles. The extended range AMRAAM variant is deemed essential to meet the MEADS requirements. However, a LCI could potentially meet this need at 5% of the cost and up to three times the range of the extended range AMRAAM variant. The time frame for MEADS fielding is 2010 to 2012. Since MEADS will share a lightweight launcher and a hit-to-kill PAC-3, development of a low cost interceptor compatible with MEADS may also offer a low cost supplemental missile to the PATRIOT force. MEADS (PAC-3) would be used to engage against TBMs and sophisticated non-TBMs, while LCI would provide a viable defense against a large number of low cost systems.

An EAAD capability is to be fielded in the 2015 time period. A stated need in EAAD concept definition is to achieve cost efficient kills against the saturating cheap air and missile threats. It is postulated that EAADS will be a suite of capabilities using advanced directed energy and kinetic energy technologies providing cost effective solutions for protection against a wide array of air and missile threats. The LCI offers a low cost, effective

solution to a significant portion of the target set for this requirement.

CONCEPT OF OPERATIONS

LCI is envisioned to be a component within the Army's future "plug and fight" concept for theater air and missile defense that will enable the defense system capabilities to be configured to the specific theater of operations. Under this umbrella of defense, the specific command and control nodes, sensor platforms, and weapons suite for the engagement will be deployed which will yield a force protection that has the optimum operational suitability while providing:

- Lethality to defeat the threat
- Strategic responsiveness getting to the fight
- Mobility to maintain OPTEMPO
- Agility to survive in the "beaten zone"
- Sustainability to provide enduring protection.

At the heart of this vision is a system tailored with architectural flexibility. As a system of systems in which any sensor data can be exploited by any tactical operations center to engage the target with the most appropriate weapon or weapons, all of the elements must be able to participate as a fully organic member to the deployed theater system with no artificial boundaries or system technical constraints and without the most debilitating short fall, organizational limitations. By providing a "net-centric" leveraging of information, a multiplier for battlefield efficiency is created. Nevertheless, the system must be adaptable to unforeseen and unfortunate loss of friendly assets and the system must be flexible to allow for graceful degradation to sustain the fight.

Operationally, target detection for the LCI system will be provided by a network of sensors, such as the Joint Land Attack Cruise Missile Defense Elevated Netted Sensors (JLENS) or an airborne system with similar capabilities, which can detect low-flying targets at extended ranges. Once detected, targeting and mission critical data would be passed to the interceptor prior to launch. Following launch, the interceptor would jettison the spent booster, start its turbo-jet engine, and deploy its wings. As depicted in Figure 2, the interceptor will then fly to the intercept location utilizing GPS-aided inertial navigation. A long-range data link on the interceptor will be utilized to allow for updates of navigation commands from the LCI command node. Such updates will allow the interceptor to adjust for target maneuvering during the interceptor's flight to the intercept location. The data link could also be utilized to capture selected frames of imagery for target verification, identification friend or foe, battle damage assessment, or other visual verification

applications. Once at the intercept location, the interceptor would initiate autonomous target acquisition.

The foundation for the baseline LCI vehicle is the Miniature Air Launched Interceptor (MALI) currently being developed by Northrop Grumman under a Defense Advanced Research Projects Agency (DARPA) Tactical

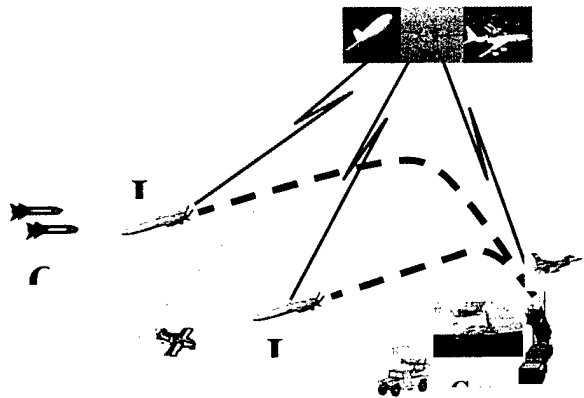


Figure 2. LCI Concept of Operations

Technology Office (TTO) Advanced Technology Demonstration (ATD). MALI has a six-inch diameter by 91-inch long fuselage and weighs approximately 100 pounds. The MALI program will provide several key items that will reduce the overall risks of the LCI development effort. Among these are a compact high-thrust turbo-jet engine and integration of an air-to-air seeker into the low-cost airframe. The LCI program will add a next generation seeker, conformal optics seeker dome, long-range data link, warhead and ground launch booster to establish the cost-effective operational capability that the Army requires by 2005 to 2007.

As illustrated in Figure 3, the LCI vehicle consists of three sections (nose, mid and aft) and a jettisonable booster. The nose section contains the terminal seeker, the warhead and the flight electronics. The fuel tank and the wings make up the mid section. The engine, actuators and tail surfaces are contained in the aft section. The basic Stinger seeker is being utilized for the MALI demonstration. For LCI, this will be upgraded to the Army's Small Diameter Anti-Air Infrared Focal Plane Array Seeker that is being developed in conjunction with Raytheon. It is intended to maintain a relatively generic seeker to vehicle interface for LCI so as to facilitate future evolution to even more advanced seekers, such as those being developed under DARPA's Low Cost Cruise Missile Defense (LCCMD) program, once those seekers are available for tactical use. Another enhancement envisioned for LCI is to modify the airframe lifting surfaces to enhance maneuverability, thereby providing an all-aspect intercept capability.

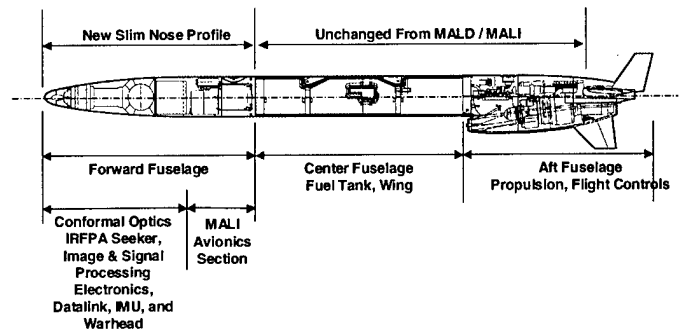


Figure 3: LCI Configuration

TECHNICAL CONSIDERATIONS

Target Detection

A critical element of the LCI system is the ability to detect small low-flying targets at long ranges. In fact, the long-range intercept capability that LCI will provide cannot be effectively utilized unless an adequate target detection capability with similar range is available. Ground based sensors cannot adequately fulfill this role because of the limitations imposed by terrain and the curvature of the earth. A target flying at 100m above ground level cannot be detected until it is within 50 Km because of the curvature. As a result, existing targeting systems such as those of Patriot, are not well suited to provide long-range detection of low-flying cruise missiles. In order to achieve such a detection capability, the sensors will need to be elevated to 10,000 feet or higher.

The Joint Theater Air and Missile Defense Organization (JTAMDO) vision for cruise missile detection is to utilize a combination of JLENS and fixed wing aircraft. This combination provides the advantages of JLENS (extended time on station and low life cycle cost) with the rapid deployment advantages of aircraft. JLENS will operate at altitudes between 10,000 and 15,000 feet to provide continuous fire control coverage against low-flying targets at ranges of up to 250 Km. Weather will have a significant influence on the availability of the JLENS system. However, incorporation of de-icing equipment, lightning protection, and wind-sensing capabilities are expected to provide 90% operational availability rate on a worldwide basis. A full capability JLENS system is planned to be completed by 2005, thereby proving the impetus for LCI, which will provide the needed kill mechanism to make use of this capability.

Information from the surveillance and targeting sensors would be provided to the command and control node, which would then select the appropriate LCI element and

prepare the necessary mission data. Once this data has been transmitted to the interceptor, the LCI would be launched. The control center would continue to monitor the target track and update the LCI navigation commands via the data link as required by changes in the flight path of the target vehicle.

The LCI primary concept of operation, airborne fire control data linked to a ground station, is only one of several modes. While the value of an airborne fire control sensor is unquestioned, the concept of operations does not demand that the data come from an airborne platform. In an era when a Single Integrated Air Picture distributed over a Joint Composite Tracking Network is available, all the LCI requires is targeting data of sufficient quality to enable an intercept. Thus, if data comes from a single airborne platform, is amalgamated over multiple platforms into a fire solution, or is provided by a ground-based platform or platforms that happen to be positioned adequately to enable sufficiently long surveillance, it is transparent to LCI. LCI will be able to perform its mission regardless of where the source of the data for the call for fires comes from.

LCI Launchers

An integral shipping/storage/launch canister is envisioned for the LCI vehicle. This canister would provide the environmental protection required while also providing the capability to mechanically and electrically adapt the canister to a wide array of launcher platforms. These launcher platforms could include MEADS/PAC-3 launcher adaptations, rail launchers, Navy vertical launch containers, or other common launcher platforms. The LCI vehicle would retain its heritage air launch capabilities as well as allowing for the inclusion of a hard back in the air launch variant.

As an example of a potential LCI launcher application, the existing PAC-3 configuration could be adapted to carry sixteen LCI vehicles. In order to accomplish this, each of the four Patriot launch cells on the launcher would be subdivided into four LCI cells. With respect to the PAC-3 configuration, the resultant LCI launcher could engage four times the number of targets at less than a quarter of the cost.

Launcher quadrant elevations of 60 to 90 (vertical) degrees are being considered. This will provide the necessary altitude for transition to the fly-out configuration and the versatility for use with the candidate launchers. A near-vertical launch attitude is also desirable in that it reduces the required safety zone for ground impact of the jettisoned boosters.

Booster

Since MALI is being designed for air launch, the boost phase will be a primary focus of the LCI design effort. The overall LCI boost requirement is to provide the vehicle sufficient altitude so that it can deploy its flight surfaces and start the turbojet engine. This process is anticipated to require up to ten seconds.

The MALI engine, which will be discussed further in a later section, is being designed to allow for starts at up to Mach 0.9 and altitudes up to 35,000 feet MSL. As a result, the desired velocity during LCI engine start is targeted to be approximately Mach 0.85. Since boost altitudes are not expected to exceed 10,000 feet AGL (20,000 feet MSL), the high altitude start capabilities of the MALI engine will not be required for the LCI application. This may allow for the elimination of some engine start system components. However, it is likely that the volume for these components in the aft fuselage section will be retained to provide commonality with potential air-launched LCI variants.

The engine is also one of the subsystems that will be a limiting factor on the longitudinal acceleration that can be imparted by the booster. The engine is capable of tolerating longitudinal accelerations of up to 25 g's. As a result, booster-induced accelerations of under 20 g's are being considered. A potential Off-The-Shelf booster that has been considered in exploratory studies is the Minimum Smoke (MS) Hellfire booster. This booster is 24 inches long, weighs 31.5 pounds and provides a total impulse of 4600 Lbf-sec over a 3 second burn time. A typical LCI launch trajectory utilizing this booster is illustrated in Figure 4.

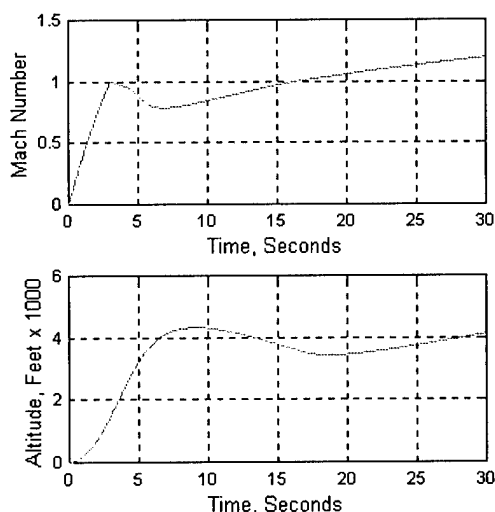


Figure 4. LCI Boost Trajectory

Stabilization & Transition To Fly-Out Configuration

Stabilization of the vehicle during the boost phase will be achieved with the interceptor's tail surfaces. If necessary, additional tail surfaces on the booster may be utilized to augment the stability. Requirements for folding of the tail surfaces remain to be established through future LCI integration activities with each of the candidate launchers.

These surfaces will be deployed immediately after clearing the launcher. Active control will be provided through the interceptor's control surfaces and use of launcher-induced spin to augment stabilization is not planned. This will minimize the cost of the launch container and facilitate the potential use of LCI from launch rails.

Following burnout, the booster and the engine inlet cover will be jettisoned, thereby preparing for the engine start cycle. The interceptor's control system will then null out angular rates and flow angularities to facilitate deployment of the wing. Once the wing is deployed, the interceptor will pitch over and establish a glide toward the first navigation waypoint. The engine start cycle and GPS acquisition will then be initiated. Once the engine has started, the interceptor will transition to the commanded airspeed and altitude contained in the navigation data provided to it prior to launch. The data link will be activated once engine alternator power is established. A thermal battery, which will be activated as part of the pre-launch sequence, will be utilized to provide power throughout the boost phase.

Airframe

Structurally, the MALI airframe will need to be modified to withstand the boost environment. The interceptor's aft section will be strengthened to provide the load path for the booster-induced acceleration. In addition, a robust, cost-effective mechanism to assure thrust axis alignment with the interceptor's center-of-gravity and effective booster jettison will be required. Since the booster propellant will be a significant fraction of the overall interceptor launch weight (15 percent in the case of the Hellfire booster), the thrust axis will need to be aligned along the longitudinal axis of the vehicle.

The current MALI airframe is designed to the longitudinal acceleration requirements associated with carrier landings. Since this is only about half of the potential booster-induced load, it is anticipated that strengthening of other interceptor structural components will be required as part of the LCI effort.

Engagement Footprint

Once in-flight, a key requirement of the LCI system is to engage the target at as far a standoff as possible. This provides for multiple engagement opportunities and assures that the potentially hazardous payload carried by the target is dispersed away from defended areas. The LCI system utilizes a compact high-thrust turbo-jet engine combined with a conformal optics seeker dome to achieve a supersonic fly-out capability and maximize the intercept range. The expected LCI engagement envelope for a low-flying Mach .85 target is illustrated in Figure 5.

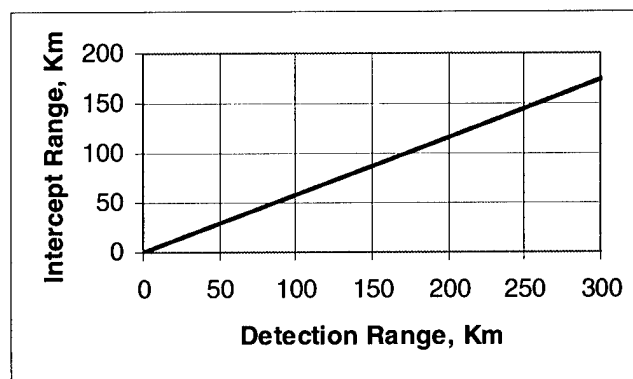


Figure 5: Intercept Range vs Detection Range

The engine baselined for the LCI is the Hamilton Sundstrand Power Systems (HSPS) TJ-50M-1. This engine is the 120-pound thrust version of the TJ-50 that is being developed as part of the MALI program. The TJ-50 heritage is from DARPA's Small Engine Advanced Program (SENGAP) and Miniature Air Launched Decoy (MALD) programs and this engine is expected to enter into production as part of the planned Air Force procurement of MALDs.

The TJ-50, shown in Figure 6, is a small expendable radial flow engine that operates on JP-10 fuel and is capable of generating 55 pounds of static thrust at sea level. The engine is 12 inches long and has a 5.4 x 6.9-inch cross-section. The larger vertical dimension results primarily from the pyrotechnic start cartridge utilized for the MALI/MALD applications. The weight of the engine is 12.3 pounds, which includes the integral fuel pump, fuel-metering valve, start system and lubrication system.

The demonstrated operating life of the engine is over 40 minutes, well within the LCI requirements, and the engine can be equipped with a shaft-mounted 1 kW alternator. The MALD and MALI applications utilize battery power and do not require the alternator. However, the use of the alternator has been baselined for the LCI configuration to

provide sufficient power for the interceptor's payload and data link.

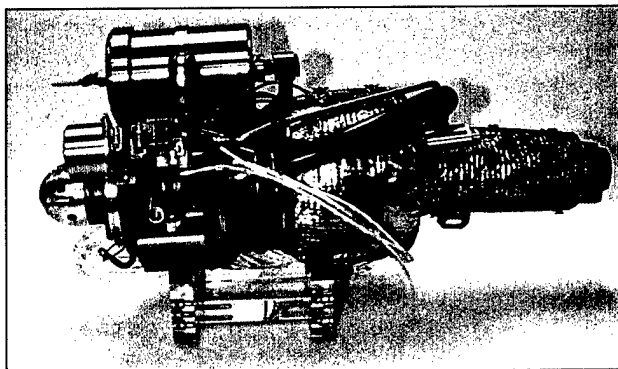


Figure 6: TJ-50 Turbojet Engine

The TJ-50M-1 engine will allow the MALI to fly at up to Mach 1.3 from sea level to 35,000 feet at Specific Fuel Consumptions similar to that of the TJ-50. The engine is currently in development and the first flight test unit is to be delivered in early 2001. The modifications that were made to the TJ-50 to increase the thrust consist of:

- a 1-inch increase in rotor diameter
- a ceramic turbine nozzle that allows an increase in turbine inlet temperature
- modification of the fuel pump to increase fuel flow
- modification of the engine inlet

The TJ-50M-1 cross-section is larger than that of the TJ-50, primarily due to the increased rotor diameter. The weight is also expected to increase by approximately 3 pounds. Confidence in the ability to achieve the engine design goals is very high as a result of ongoing risk reduction testing with the TJ-65 hardware, which is a sub-scale version of the M-1 design. In production, the TJ-50M-1 engine is projected to account for less than ten percent of the overall LCI Average Unit Fly-Away Price (AUFPP) goal.

On MALI, forebody drag is minimized during fly-out through the use of a cap over the seeker dome that provides a high-fineness ratio aerodynamic contour. While this provides the desired aerodynamic performance, it presents several significant challenges for operational use, namely the attachment and jettison of the cap. The baseline LCI concept overcomes these challenges by leveraging Conformal Optics Technology for the seeker dome. This DARPA/AMRDEC developed concept provides the high-speed, low-drag aerodynamic

seeker dome contour while maintaining the optical performance of the seeker.

Traditionally, applications of optics have been driven by the practical limits of designing and fabricating optical systems. Optical systems employed on military missile systems using infrared (IR) sensors typically use technology limited shapes such as hemispheres. Technology was pursued and developed to produce a new class of optics called conformal optics. This technology has demonstrated the viability of designing optical systems that conform to and are optimized for the environment in which they are to be employed. In the case of missiles, optical systems will no longer be constrained to simple shapes such as hemispheres. They can now be aerodynamically optimized leading to real payoffs in terms of drag reduction, range extension, time of flight reduction, radar cross-section reduction and lethality improvement. The optical characteristics of a conformal dome are maintained through the use of a secondary lens located between the dome and the seeker.

Typically, half the total missile drag is due to the nose. If the traditional spherical nose of a missile employing optical seekers is stretched along the longitudinal axis, the result is a family of ellipsoidal shapes as illustrated in Figure 7.

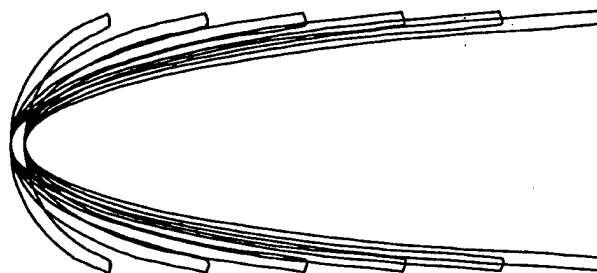


Figure 7: Ellipsoid Optics Family

This ellipsoidal family is ideally suited for application as conformal domes since it fulfills the basic requirement for shape continuity in the first and second derivative. In addition, there is a large amount of high-fidelity drag data for this family of shapes and the shapes can be easily defined mathematically. As the aspect ratio of the ellipsoid is increased, significant drag reductions can be achieved as indicated in Figure 8.

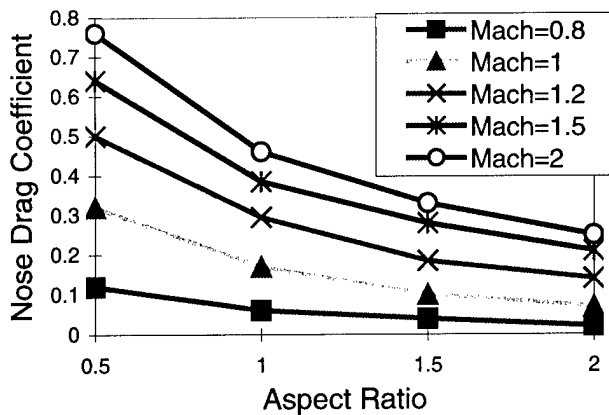


Figure 8. Nose Drag Coefficient vs. Aspect Ratio

The above figure provides the nose drag coefficient as a function of its aspect ratio, where the aspect ratio is defined as the ratio of dome length to diameter. The traditional hemispherical dome has an aspect ratio of .5 and is typical of most missiles using optical seekers. A conformal optics seeker having an aspect ratio of 1.5 has been developed and successfully tested. As the figure indicates, such a conformal dome reduces the nose drag by a factor of 2, resulting in a 25 percent reduction in missile drag and a corresponding 25 percent increase in missile range.

Data Link

LCI will incorporate a long range datalink for command and control and for the transmission of seeker imagery. The datalink (Figure 9) will utilize technology similar to that developed under the AMRDEC Future Missile Technology Integration (FMTI) Technical Demonstration. Operating in the low microwave band, the datalink will be capable of down-linking 1 image every 2 seconds and up-linking data at a rate of approximately 16 kbits per second. Techniques for low probability of intercept and auto-jamming will include frequency hopping, direct sequence coding and RF power management. In order to insure the datalink is robust against jammers, a spread spectrum approach will be employed. 360 degrees of coverage will be provided through use of conformal sector array antennas.

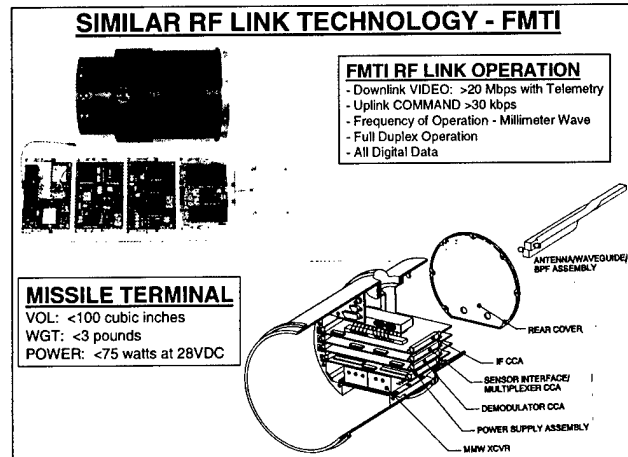


Figure 9: FMTI Data Link

Navigation

Interceptor navigation during fly-out will utilize waypoint navigation. The LCI Command and Control function will provide waypoint data (location, altitude and airspeed) prior to the launch of the interceptor. GPS-aided inertial guidance will be utilized to navigate the specified waypoints. The final waypoint will be the projected location of the target upon arrival of the interceptor. The seeker will autonomously initiate its search pattern upon arrival at the intercept waypoint. Following target acquisition and lock-on, the seeker will provide navigation commands to complete the terminal engagement.

Intermediate waypoints will allow for shaping of the fly-out trajectory for deconfliction of the interceptors with other friendly airborne platforms. The data link will allow for updating of navigation commands if the projected intercept point changes due to heading changes of the target. This will also allow each interceptor to be reassigned to another target during fly-out. Such a reassignment could occur if the initial target ceases to be a threat or if a higher priority time-critical target pops up after interceptor launch.

Seeker

The Army's Small Diameter Anti-Air Infrared Seeker program developed and demonstrated an imaging IR seeker for a small diameter missile airframe. This seeker can provide improved target engagement capability for air defense missile systems, such as the LCI program.

The LCI baseline seeker design utilizes a staring IR Focal Plane Array imaging seeker concept. This array is a mature 128x128 InSb mid-wave IR array, currently in production. The collecting optics design is based on a

zinc sulfide solid catadioptric single element. The seeker electronics are contained in the Guidance Electronics Assembly (GEA) attached to the rear of the seeker head. This package consists of five Multi-chip Modules (MCMs) and a forward and aft interface. MCM-technology is used to fabricate three of the MCMs as a single layer cap on a Printed Wiring Board Core. Two of the MCMs are double layered and are more dense and require a low density co-lamination process consisting of a 2 - 6 layer cap using low-density bond ply with a PWB core. In the future, full co-lamination may be implemented using layer pair construction with high-density bond ply and thermal core. Each MCM is dedicated to a particular seeker function. The MCMs are interconnected using a grid of gold-plated brass balls around the outside edge of each MCM both front and rear. The MCMs are connected using fuzz button rings between the MCMs. The compression from the attachment of the forward and aft interfaces provides compression allowing positive contact. The majority of the electronics within the GEA are implemented in 3.3 volt logic to minimize power consumption and resulting heat generation.

Demonstrations of the seeker head design in FY 99 utilized tactical-sized electronics and highlighted target acquisitions in clutter backgrounds and in the presence of IR countermeasures (IRCCM). The FY99 Demonstrations also included captive carry testing along with missile flight simulations. As a result, this seeker will enable LCI to engage targets in the presence of ground clutter at ranges well in excess of previous IR seeker capabilities.

Maneuverability

A rear attack approach is being utilized for the MALI program. This was selected to meet the intercept requirements while minimizing the airframe and seeker performance needs and cost. The performance of the baseline LCI interceptor will be enhanced to fulfill the Army's all-aspect intercept needs.

Maneuverability enhancements being considered for LCI consist of a new tail configuration and additional lifting surfaces. The tail modification would be to replace the current MALI tail with a cruciform configuration. The MALI configuration utilizes two actuators. All four of the LCI tail surfaces would be actuated to provide the lateral-directional control needed for all-aspect intercepts.

The basic MALI airframe configuration can provide an instantaneous longitudinal turn rate of approximately 5 g's. Modifications to the airframe will increase this to 9 g's for LCI. Addition of mid-body strakes is being evaluated as a means to attain this capability. Addition of

vertical strakes is also being considered to provide a greater skid-to-turn maneuverability.

Warhead

The LCI warhead would be carried in the nose section in-between the seeker and the flight avionics. A proximity fuse would be utilized to detonate the warhead. Several Off-The-Shelf (OTS) warheads are being considered for use on LCI. Final selection of a warhead will be made during the LCI development program.

Collaborative Formation Flight Operations

Use of collaborative formation flight will enable autonomous co-operative engagements between multiple interceptors and will significantly enhance the flexibility of the LCI concept. Such operations would involve communications between groupings of interceptors and the use of hierarchical leader-follower logic. This would allow the redirection of the designated grouping leader and the remainder of the grouping would autonomously adjust accordingly. As a result, the command and control system would only need to actively control one vehicle in each grouping, thereby greatly reducing the command and communications requirements for a many-on-many engagement.

Use of collaborative formation flight would also allow for enhanced terminal engagement effectiveness. If the first interceptor to an intercept point fails to acquire the target, then it could leave that target for another interceptor and fly on to a secondary target in the area. In a target-rich environment, this would be a more effective use of terminal engagement time than turning around and making another pass to acquire the initial target. Conversely, if the lead interceptor acquires and engages the target, then the remaining group members would autonomously redirect to their next highest priority target.

Autonomous co-operative operation of multiple MALDs in formation flight will be demonstrated during one of the upcoming MALI program flight tests. During this test, three vehicles will be launched and then flown in a pre-assigned formation. During the flight, pop-up threats will be introduced to assess autonomous reactions. The vehicles will utilize neural network algorithms to determine the best means of avoiding the threat and adjust their navigation along the new route. In addition to this, the vehicles will demonstrate autonomous creation and modification of formations.

SUMMARY

The continuing proliferation of low-cost cruise missiles is becoming a significant threat to U.S forces and interests

around the world. In order to effectively counter this threat, a Low Cost Interceptor (LCI) is needed. LCI must be capable of engaging this threat at extended ranges, must be cost effective (<\$100K) and needs to be fielded by 2005 to 2007 to minimize exposure to the threat. LCI is required to augment other air defense assets that are intended to address the more stressing ballistic missile threat. As a result, these other assets cannot cost effectively address the low-cost cruise missile threat, especially for those scenarios in which repeated swarms of cruise missile are utilized.

The proposed LCI concept provides a low-risk approach to meeting the Army's air defense requirements by leveraging several existing technology development efforts. Among these are DARPA's Miniature Air Launched Interceptor (MALI) and Conformal Optics programs, which will provide the compact high-thrust turbojet engine and high-speed aerodynamically contoured seeker dome for the LCI vehicle. The baseline seeker is the Army's Small Diameter Anti-Air IR Focal Plane Array and the command and control data link will be evolved from the Army's FMTI program. These interceptor technologies, coupled with the detection of low-flying targets at extended ranges, will enable the cost effective LCI system needed to counter this threat.

Army plans call for development of LCI through an evolving Advance Technology Demonstration (ATD) in support of the U.S. Army's PEO, Air and Missile Defense. The Army's Aviation and Missile Command (AMCOM) Research, Development and Engineering Center (RDEC) and Space and Missile Defense Technical Center (SMDTC) are teaming to execute the effort, with RDEC focusing on the first increment of interceptor and launcher integration and SMDTC focusing on C4I, Battle Management and evolving interceptor technologies.

Government Disclosure Authorization Form

Disclosure authorization is required for all presentations. If this form is not received prior to the meeting the presentation will be canceled.

PART I

Name of Author(s) GARY T. SIMMERSON & HANS J. BALL

Title of Paper: APPLICATION OF LOW-COST TURBO-SET POWERED
INTERCEPTORS FOR CRUISE MISSILE DEFENSE

Classification of Paper/Presentation (circle one) SECRET CONFIDENTIAL UNCLASSIFIED

Author's Signature: [Signature]

PART II RELEASING OFFICIAL

Name of Releasing Official: Julian L. Cothran

Title: Chief, Design and Analysis Function, Propulsion & Structures Directorate,
AMRDEC

Address: AMSAM-RD-PS-SA
Redstone Arsenal, AL 35898

Telephone Number: (256) 876-7424

The Releasing Office, with the understanding that all attendees have current security clearances and that all attendees have approved need-to-know certification, and that no foreign national will be present, confirms that the overall classification of this paper is UNCLASSIFIED and authorizes disclosure at the meeting.

Classified by: N/A Declassify on: N/A

Distribution Statement: Open Literature*

Releasing Official's Signature: [Signature]

* DISTRIBUTION STATEMENT A: APPROVED FOR PUBLIC RELEASE;
DISTRIBUTION IS UNLIMITED.